WORKSHOP ON CALCULATION OF BWR FUEL ISOTOPIC COMPOSITION

<u>UPM activities</u>:

- Neutronic/Thermohydrulic (COBRA-TF) coupling

- Inventory prediction using SCALE6.1

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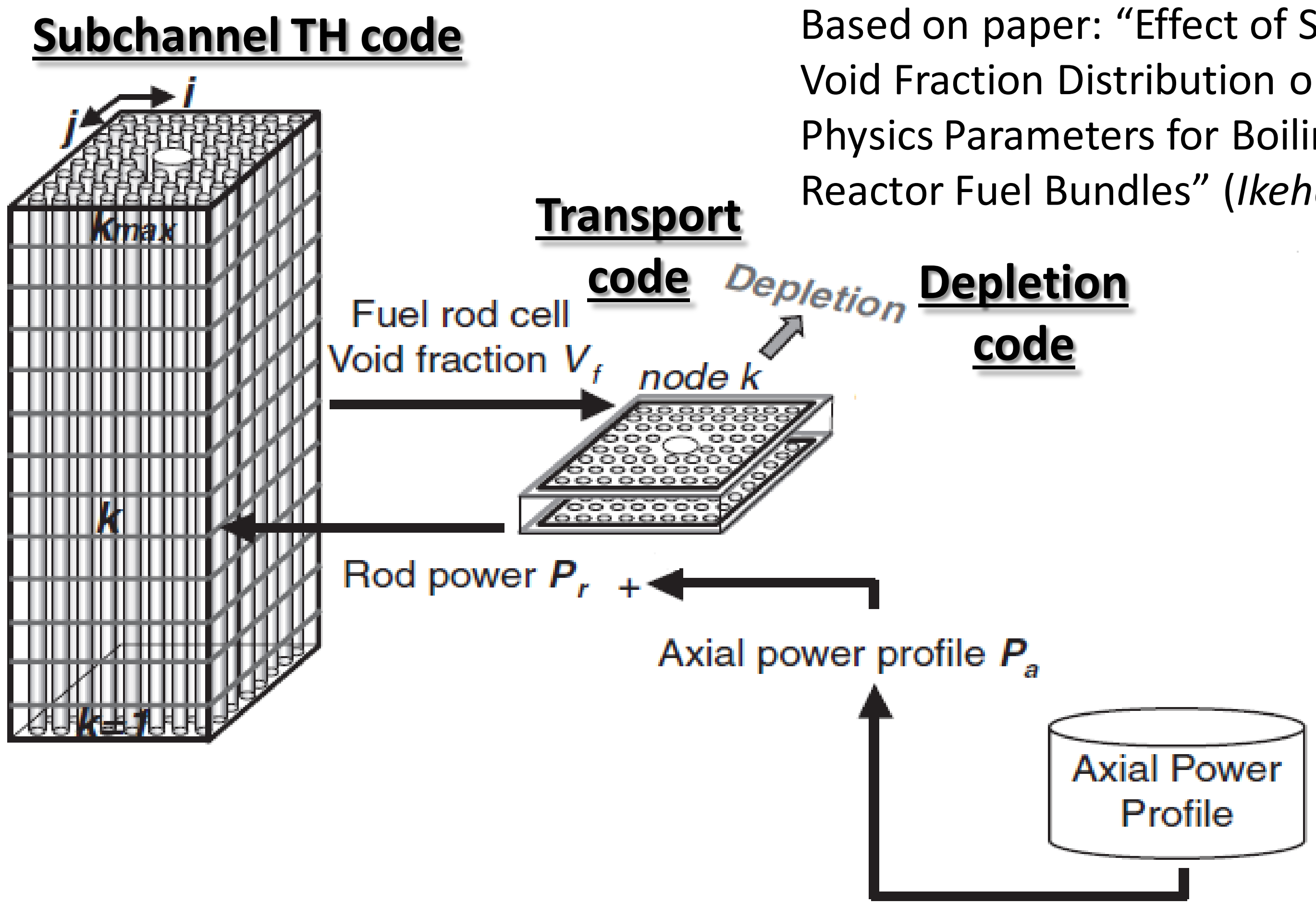
Goal

Tool to couple neutronic and thermal-hydraulic calculations in order to perform BWR burnup analysis

- TH 3D calculations
- N 2D calculations
- Depletion 2D calculations
- Axial power distribution determined by the core design analysis

Improve BWR isotopic evolution and/or distribution; reduce differences between simulation results and experimental data

Calculation model



Based on paper: “Effect of Subchannel Void Fraction Distribution on Lattice Physics Parameters for Boiling Water Reactor Fuel Bundles” (*Ikehara et al.*)

- Axial power distribution determined by the core design analysis: $P_{a;k}$
- When N-TH iteration finished → $V_{f;k}$≈cte during depletion

Codes

Neutronic 2D calculation **NEWT**

Depletion 2D calculation **TRITON**

Isotopic calculation **ORIGEN-S**

- NEWT and TRITON calculations at each of the 25 nods are performed in parallel

↓↓↓ computation time

- Parallel programming software: **MPI**
  - Macros and functions library

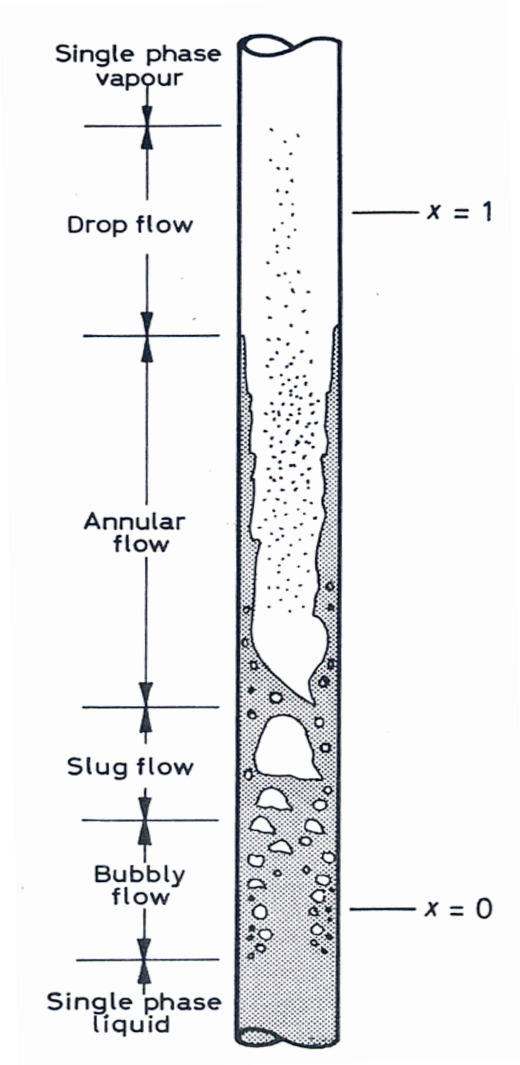
Codes

TH 3D calculation **Subchannel analysis codes**

- Detailed model of the subchannels geometry within the fuel assembly
- Can predict radial void distribution at each axial level
- Codes used:

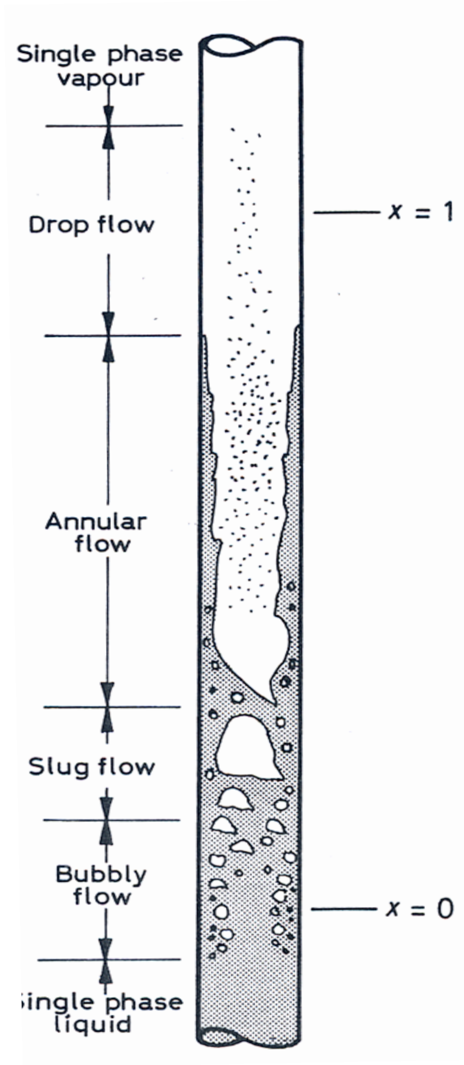
  COBRA-EN

  COBRA-TF



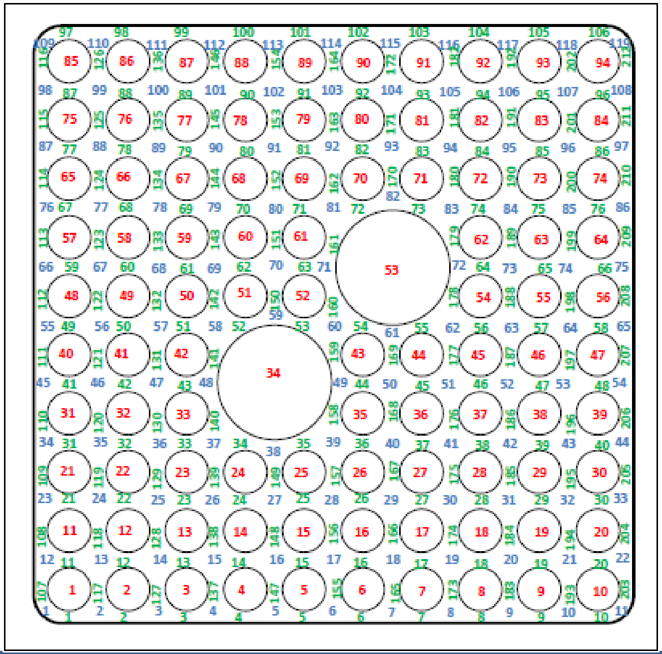
Codes

- **COBRA-EN**: Three equations model, mixture
  - Good results at very low void fractions
  - Easy geometry definition
  - Drawbacks:
    - Unable to define different geometry sections: vanishing and dominating
    - Correlation for void fraction: poor results when void fraction becomes significant
- **COBRA-TF**: nine equations model, two-fluids, three fields
  - Complete separation of vapor and liquid
  - Can predict with higher accuracy annular flow regime at high void fraction
  - High flexibility of geometry definition including different axial sections
  - Drawback:
    - Complex definition of geometry
    - Long calculation time, short compared with NEWT



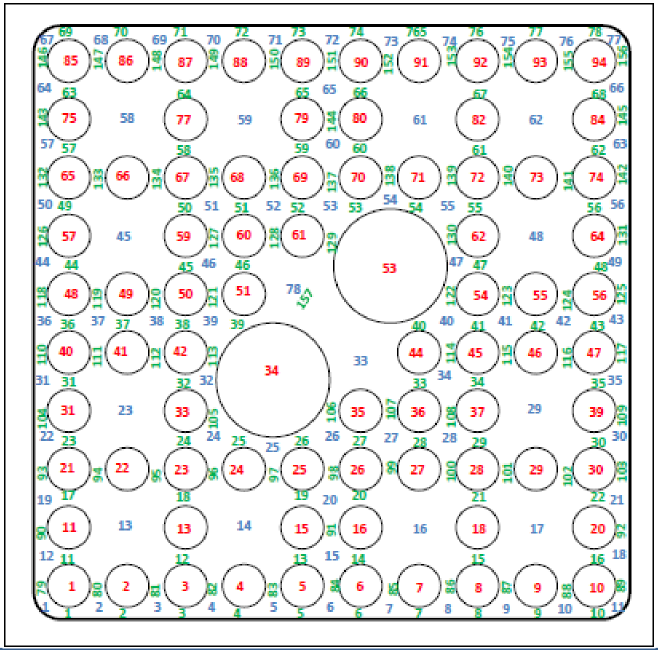
Considerations

- Subchannel code should predict **average radial void fraction** for each axial node given at the benchmark specifications
- There are two sections included in the assembly with distinctive geometric definition
    - Conventional subchannel geometry with water holes



Considerations

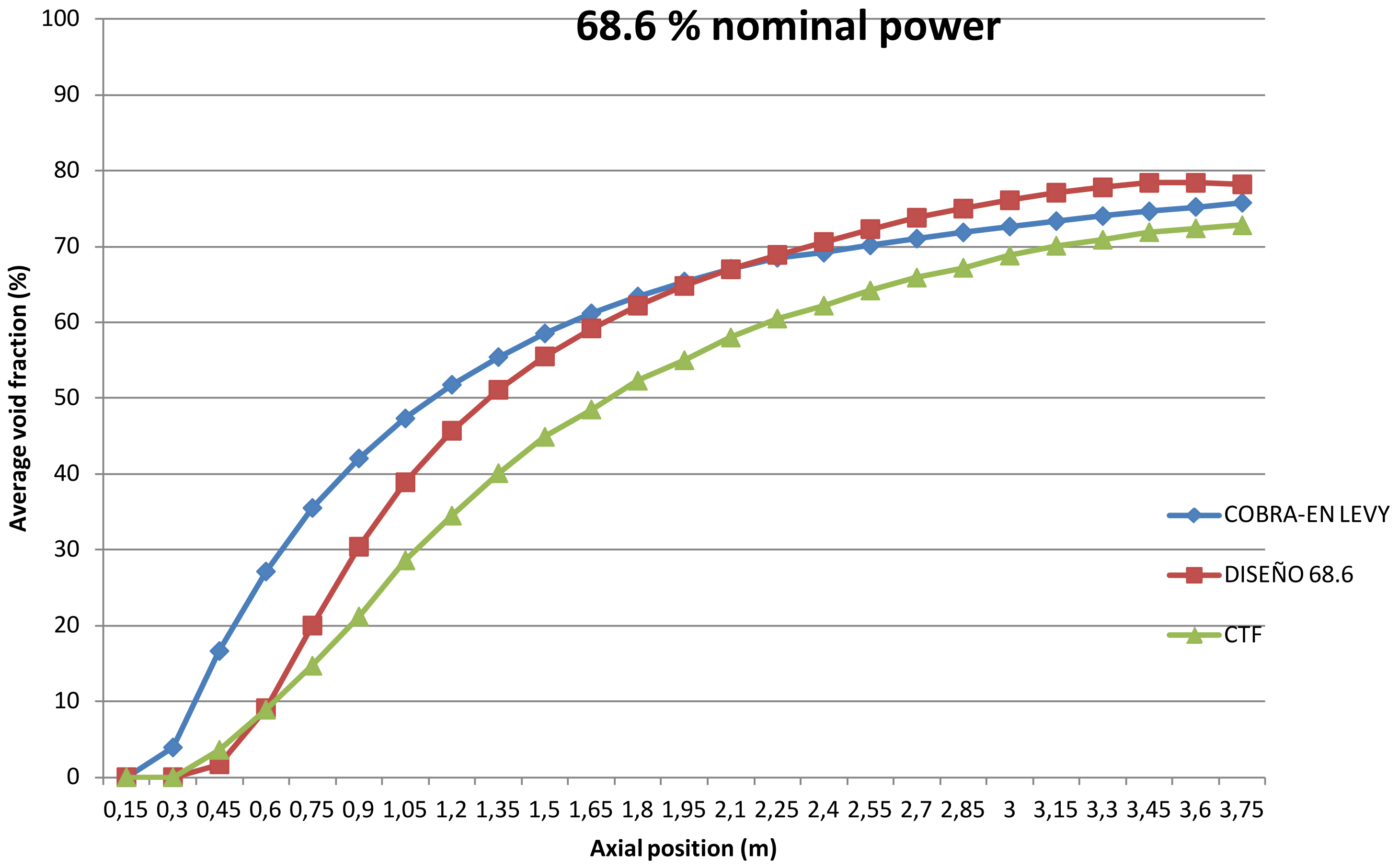
- Subchannel code should predict **average radial void fraction** for each axial node given at the benchmark specifications
- There are two sections included in the assembly with distinctive geometric definition
  - Non-conventional subchannel geometry:
    - ✓ Partial power rods
    - ✓ Exotic subchannel shapes



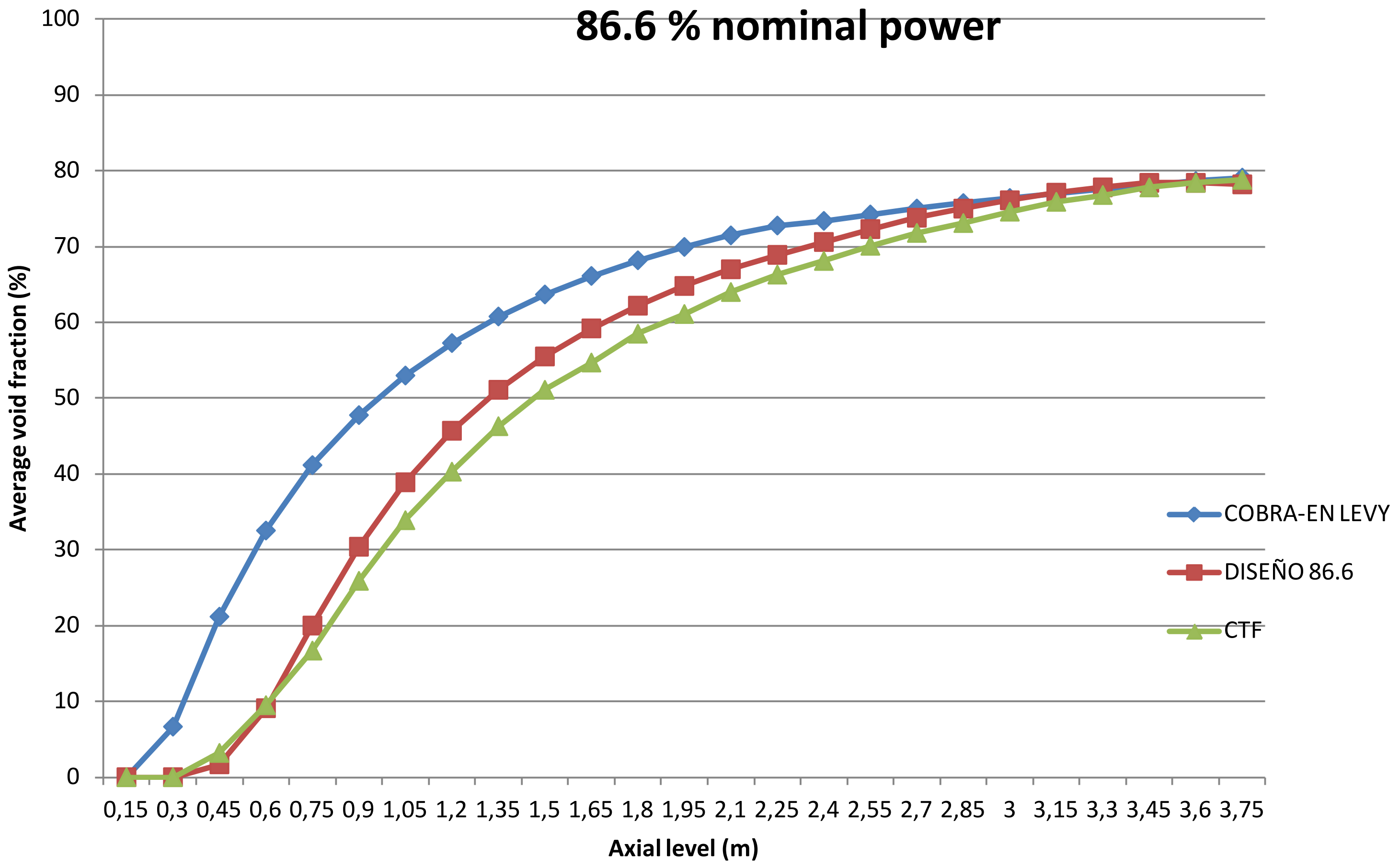
Considerations

- COBRA-EN unable to simulate directly partial rods
  - Two steps calculations were defined:
    - Dom (inferior) last axial level variables distributions are used as boundary conditions for van (superior) section
- COBRA-TF can define two sections
  - Due to the complex definition of the model, first results were obtained with one section (dom) for the whole assembly
  - Two sections model is already working although results were not yet analyzed

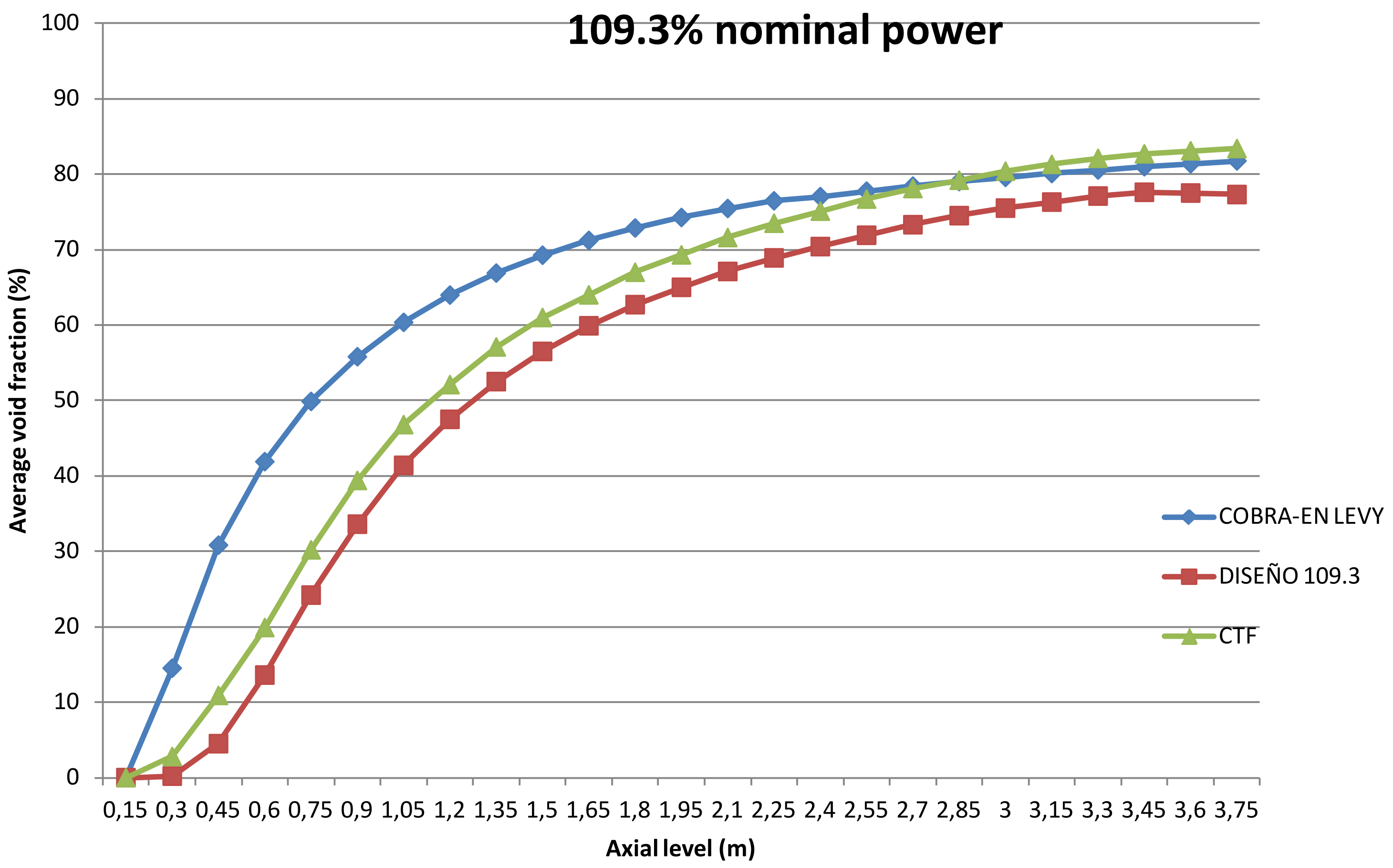
Average radial void fraction comparison



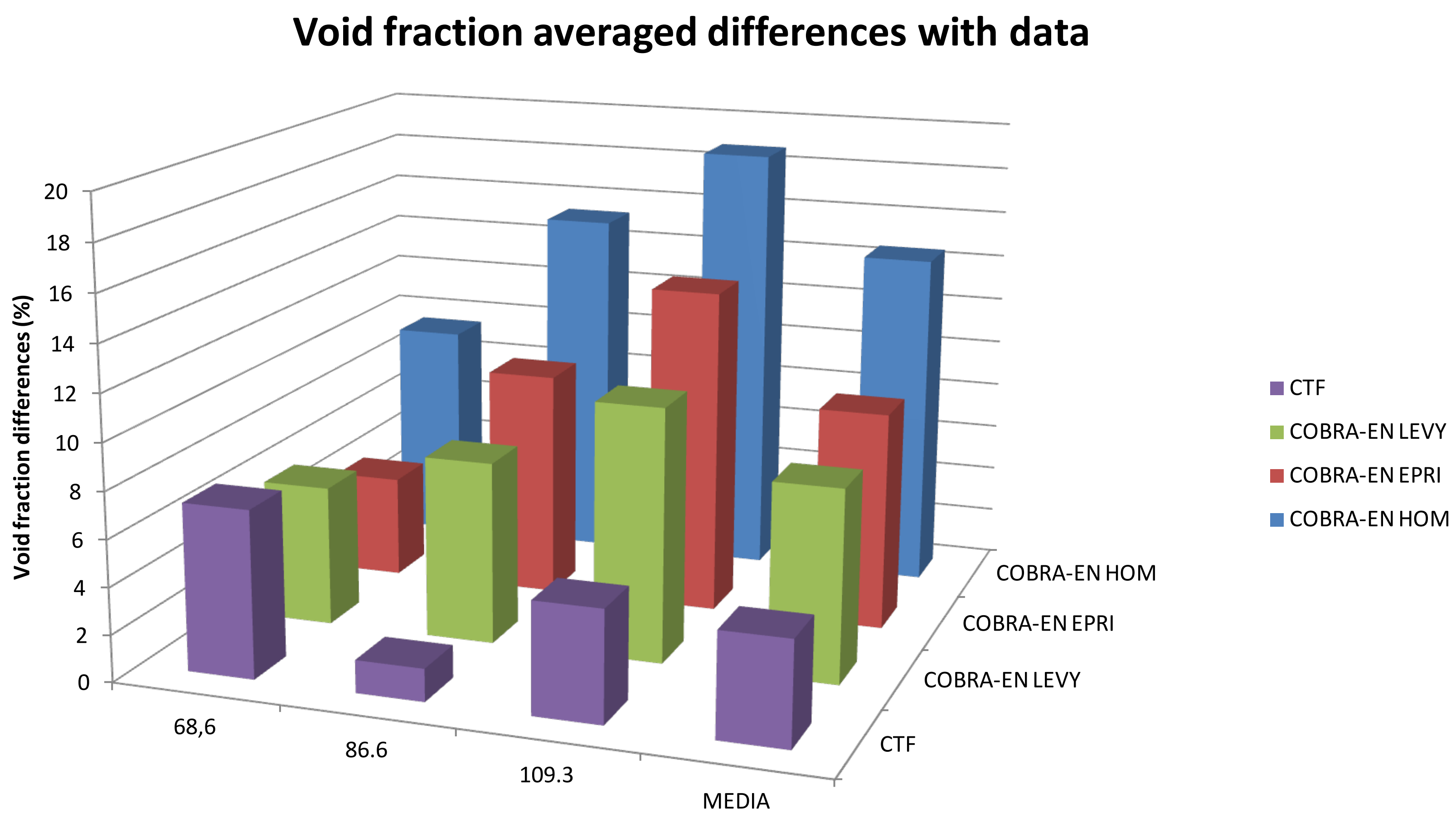
Average radial void fraction comparison



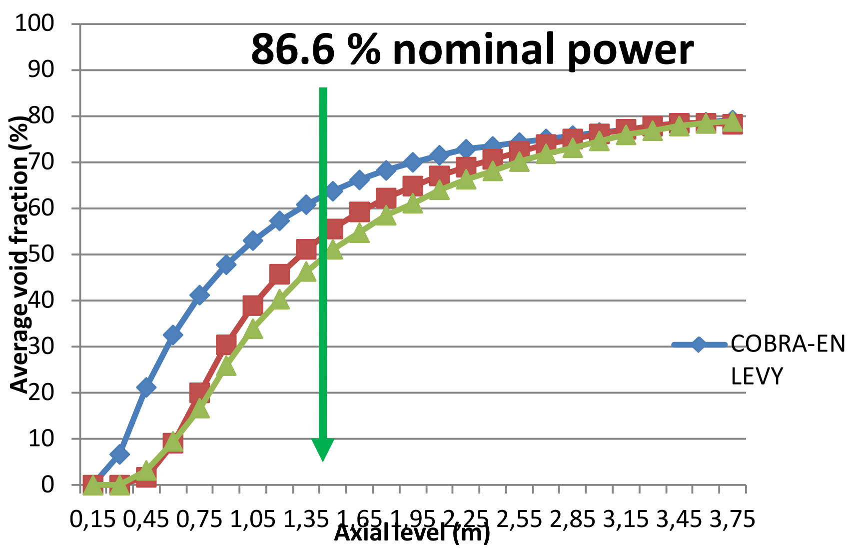
Average radial void fraction comparison

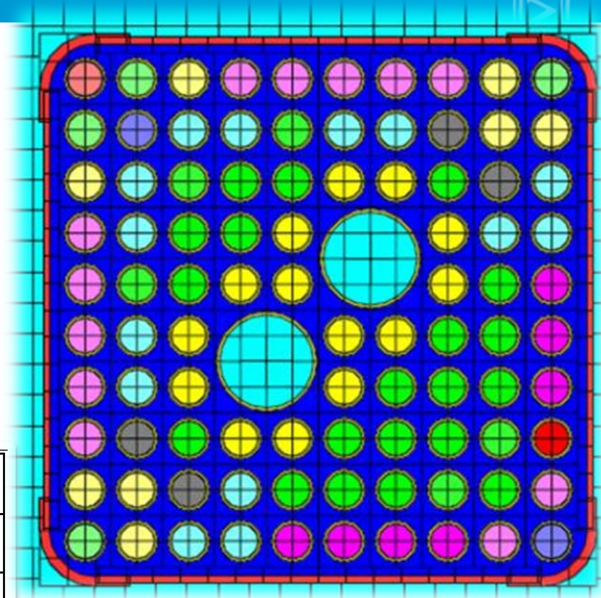


Differences with data



Void distribution





31,3	33,1	33,6	33,5	33,9	33,6	33,8	33,5	33,4	33	31,1
33,1	54,9	54,6	54,3	54,6	54,6	54,7	54,6	54,4	54,9	33,3
33,6	54,5	54,1	53,6	53,7	54	54,2	53,8	53,7	54,6	33,4
33,9	54,6	53,7	54,1	55	36,7	46,4	35,2	54	54,7	33,7
33,7	54,5	53,7	54,4	55,5	47,6	X	46,1	54	54,7	33,8
33,6	54,7	54	35,9	47,7	22,6	47,7	36	54	54,7	33,6
33,8	54,7	54	46,2	X	47,6	55	54,4	53,7	54,5	33,7
33,8	54,7	54,1	35,2	46,4	36,7	55	54,1	53,8	54,6	33,8
33,4	54,6	53,7	53,8	54,3	54,1	53,7	53,6	54	54,6	33,5
33	54,9	54,6	54,5	54,7	54,6	54,5	54,4	54,6	55	33
31,2	33,3	33,4	33,5	33,9	33,7	33,8	33,5	33,6	33	31,2

Void distribution at 1.35m axial level (CTF 86.6%)

Conclusions and ongoing work

- Conclusions
  – Coupled N-TH tool on development can use COBRA-TF as TH code for radial void distribution
- Ongoing work
  – COBRA-TF integration in the coupled tool
  – Parallel NEWT calculation at the 25 nods defined in the specifications